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Operational Efficiencies of Truck Inspection Stations

Truck Inspection System Study

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FOREWORD

This report is one in a series of fact-finding projects studying the Ontario Truck Inspection System. The other projects deal with conviction profiles, compliance rates, mobile inspection efficiency and behavioural/ economic factors in compliance.

This report presents the approach and findings of the computer simulation of truck inspection station designation and operation. This model provides management with a powerful tool for the efficient allocation of scarce resources.

Although Mr. Agarwal managed the project, he left the Ministry prior to receipt of the final report from Proctor and Redfern. The final technical editing was completed by Frank D'Onofrio, Research Assistant, and myself.

Richard Slocum
Study Co-ordinator
December 1981

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The Co-ordinating Committee had the following membership:

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EXECUTIVE SUMMARY

The purpose of this study was to determine operational efficiencies of truck inspection stations of various layouts, and their relationships with the inspection facilities, number of assigned staff, inspection schedule, truck traffic volume, and the nature and degree of violations. This study provides:

- a basis for deployment of inspection resources to achieve optimum efficiency for all types of truck inspection stations;
- potential modifications to improve the operational efficiencies of the truck inspection stations;
- a measure of time delay to the truck operators resulting from the inspection.

A computer program was developed to simulate the operations of stations in which the above mentioned factors could be varied. This program was used to develop a series of charts (for "typical" stations) which provides insight into the general principles of station operations under varying conditions.

The salient observations from these charts with respect to the two major areas of concern, namely delays to trucks using the stations and the efficiency of detecting infractors are as follows:

- Except for very low volume stations, a large proportion of infractions cannot be detected using the existing operational methods. This confirms the field data on infraction detection efficiency from a previous study [2].
- The average delay to trucks at one-man stations is much higher than at multi-man stations. This is because, in the case of a thorough inspection, the inspector first weighs the truck and then leaves the weigh house to complete the non-weight inspections. At a multi-man station the non-weight inspections can be done while the trucks are being weighed, or waiting in the queue to be weighed.

- At multi-man stations the delays to trucks **increase** as the crew size increases. The explanation for this is that, as the crew size increases, a greater proportion of the trucks receives more thorough stationary inspections.

- The total number of infractions detected increases with increasing crew size. However, the number of weight infractions detected is insensitive to the crew size, since the number of trucks that can be weighed is determined by the weighing capacity of the scale rather than the crew size. Therefore, if the objective is to increase the detection of weight infractions, an increase in crew size will not be effective.

A number of methods to increase the efficiency of stations were identified, e.g., reducing the queue length in the weigh lane, increasing manpower, increasing the surveillance period (more than one shift per day), changing the station layout, and the pre-screening of trucks for inspection. However, one of the major disadvantages to increasing enforcement is the increase in delays to complying trucks.

Techniques to assess these improvements were developed so that the major components of station efficiency, namely, operating costs, delays to trucks and infraction detections can be taken into account.

A series of simulations for eight specific stations was completed and the simulated performances compared with field data. In most cases the weight infraction detection efficiency from station records was equal to, or higher than, predicted by the computer simulations. The non-weight infraction detection efficiency from station records was often lower than that predicted by the computer simulations. This confirms the present feelings of supervisory staff that more emphasis is given to weight infractions than non-weight infractions.

Since the simulations use a rigid inspection procedure and input that is often averaged from a number of stations, the simulation output can vary significantly from field data at specific stations. However the simulations provide "bench mark" performance indices which can be used to iden-

tify major performance problems and to assess alternative methods for optimizing efficiency.

The techniques to assess improvements for "typical" stations were used to identify potential areas for improvement for the eight specific stations.

One method of increasing station efficiency that may be adopted in the future is the pre-screening of trucks for stationary inspections. This method shows the greatest potential for improving efficiency of stations, since it will increase the detection of infractions, and at the same time, will reduce the delays to complying trucks. The use of weigh-in-motion scales could be used to pre-screen trucks for stationary weight inspections. The computer simulation program developed for this study includes options to assess the effects of pre-screening of trucks for stationary inspections so that it will not be obsolete if effective pre-screening programs are introduced. A hypothetical example comparing the operation of a station with and without pre-screening is shown to illustrate the potential of pre-screening for increasing station efficiency.

The methodologies developed in this study should provide useful tools for the understanding and assessment of the operational efficiencies of truck inspection stations. In addition this study has application outside its present scope, e.g., the development of staff training programs, the design of future stations, cost benefit studies for stations as a means of enforcement, monitoring highway infraction rates, and as input into the assessment of the overall truck enforcement program.

Since it is unlikely that total enforcement is possible, it is recommended that priorities should be established for levels of enforcement of the various types of infractions and acceptable delays to complying trucks.

Once these priorities have been established this study can provide much of the information necessary to achieve these goals.

PART A

INTRODUCTION

1/ INTRODUCTION AND ORGANIZATION OF REPORT

1.1/ Introduction

The use of Truck Inspection Stations is part of the Ministry's program to enforce and monitor compliance within the trucking industry with respect to four major concerns:

- vehicle weight and load distribution;
- vehicle dimensions;
- safety and mechanical fitness of vehicles;
- the Public Commercial Vehicles Act conformance.

At present the Ministry operates 48 stations throughout the province, at an estimated annual operating cost of $5 million.

The study of Truck Inspection Stations was initiated to assess the effectiveness of this part of the enforcement program and to determine if any improvements in efficiency could be realized.

This study was undertaken simultaneously with other studies addressing other aspects of the truck inspection program, specifically studies on the efficiency of mobile inspection units [1], truck compliance on the road system [2], behavioural aspects of compliance (economic and human) [3], and a profile of violators [4].

It is understood that the various studies may be combined to assess the overall program in enforcing truck compliance. One example of how all the studies may be integrated to assess the overall enforcement program is described by the conceptual model shown in Figure 1. The objective is to modify driver behaviour in order to increase compliance (see shaded box).

As can be seen from the flow chart, the truck inspection station study should provide the following information so that it can be integrated with other studies in the overall enforcement model:

- the probability of detection for non-complying trucks;
- delays to trucks using stations;
- the costs of various levels of enforcement at stations.

The study was therefore designed so that the information developed could be used to assess the efficiencies of stations as an isolated operation and also as input to the overall evaluation of the truck compliance enforcement program.

1.2/ Organization of the Report

Part A of this report describes the purpose and scope of the study.

Part B describes the existing operation of the various types of stations and analyzes data collected on the existing operations.

Part C describes the development of the simulation model through the use of flow charts and how the model was validated.

Part D describes how the output irom the simulation model was used to develop general principles for the operational efficiency of "typical" stations.

Part E describes methods of improving station operational efficiency for stations in general, some of which are based on the principles developed in Part D. The simulation output for eight specific stations is discussed, and the existing performance of these stations evaluated. Potential improvements to the existing operation for each station are identified.

2/ PURPOSE AND SCOPE OF STUDY

2.1/ Purpose

The purpose of this study is to assess the operational efficiencies of stations as related to their:

- operational procedure,
- layout,
- number of inspectors,
- truck traffic volume handling capabilities,
- nature and degree of infractions, and
- inspection schedule.

2.2/ Application of Study Findings

The study provides information that can be used:

- as a basis for the deployment of inspection resources in order to achieve optimum efficiency for all types of truck inspection stations;

- as a basis for implementing modifications to improve the operational efficiencies of individual stations;

- as a measure of time delay and inconvenience to the truck operators using the stations.

It should be noted that much of the information contained in this report is of time-limited relevance. For example infraction rates, truck volumes, staff scheduling, inspection times etc. may change with time. However, since this study is based on a simulation model, the information contained in this report can be updated using current data as input.

2.3/ Major Study Activities

The study involved the following:

- a detailed study of various stations throughout the province, in order to gain an in-depth understanding of the operation of various types of stations;
- identifying those factors which affect the operation of various types of stations;
- formulating the operations of the various types of stations into tight logical structures, through refined, detailed flow charts;
- developing a computer model to simulate the operation of various types of stations under varying conditions;
- testing and validating the simulation model by assessing the logic of the output; and by comparing the output against observed field data;
- general sensitivity testing of various factors such as weighing times, station layout, crew size etc., and developing efficiency charts for "typical" stations;
- applying the computer model to eight specific stations to evaluate their operational efficiency, and recommending improvements where possible.

2.4/ Extended Applications

In addition, this report can provide a basis for other studies including:

- testing various policy options,
- developing design guidelines for future stations,
- developing staff training programs,
- testing various improvements or modifications,
- testing different staff scheduling programs,

- monitoring the performance of stations,
- monitoring the compliance of trucks at various stations to test the effectiveness of enforcement, and
- as input to other studies.

Although the computer model developed in this study simulates a definite sequence of operations, based on the current observed operations of stations, it could readily be adapted to other modes of station operation, for example:

- stations with weigh-in-motion scales (no changes to existing computer program required), and

- stations with more than two inspection lanes as compared to the two (one weigh and one passing lane) employed at present (modification of the computer program would be required).

PART B

EXISTING STATION OPERATION

3/ DESCRIPTION OF EXISTING OPERATIONS

This section describes the present operations at Truck Inspection Stations. The method of operation may vary slightly at certain stations due to unusual layouts and different operating procedures employed by the supervisors. These variations are described where applicable in Section 9 of this report.

Truck Inspection Stations are located adjacent to the highway, and commercial vehicles are required by law to enter if the station is open. (See Figure 2). The following inspections may be carried out at the station:

- weighing of axle loads, and measuring of vehicle and load (Highway Carrier Inspectors);
- inspection of truck, vehicle licensing and other pertinent documents (Highway Carrier Inspectors);
- safety and mechanical fitness checks (Motor Vehicle Inspectors);
- gasoline/diesel fuel tax receipts, radar detectors, alcohol/drug abuse (Revenue Officers, O.P.P.).

A chart detailing the inspection procedures at a station is shown in Figure 3.

In addition, other services are provided, including information concerning trucking regulations, issuing of permits (e.g., overload permits), weighing of trucks for truckers' information (e.g., the unladen weight of trucks), a public telephone booth, and a layby to allow truckers to check their vehicles.

However these additional services are provided infrequently and do not affect the operation of most stations significantly. One of the exceptions is stations at border crossings where permit issuing may represent a significant part of the workload. Stations at border crossings have not been considered in this study.

3.1/ Types of Truck Inspection Stations

The various types of stations have been categorized according to their geometric layout since this affects the operation of the station.

There are three broad categories of geometric layout (see Figure 4):

- two-way straight layout
- one-way straight layout
- one-way racetrack layout

3.1.1/ Two-Way Straight Layout Station

This type of station is located on a two-way highway where truck volumes are low enough to permit trucks to enter the station from both directions.

3.1.2/ One-Way Straight Layout Station

This type of station is located on both divided and undivided highways and handles a complete range of truck volumes. As the name suggests, the trucks enter the station from one direction only.

3.1.3/ One-Way Racetrack Layout Station

This type of station is located on freeways where high truck volumes are encountered. The feature that distinguishes this station from the one-way straight layout is the circular driveway around the back of the station building. This allows trucks to re-enter the weigh lane for a reweigh by driving around the station building without disruption to the weigh lane truck flow. The circular driveway is part of a large parking area at the back of the station whfch allows safe parking for trucks.

3.2/ Components of Station Operation

The station operations include the following:

- truck sorting,
- weigh lane operation,
- weight adjustments,
- passing lane operation,

- mechanical checks,
- violation processing, and
- truck impounding.

3.2.1/ Truck Sorting

This is the process by which trucks are assigned to the weigh or passing lane.

Based on discussions with inspectors, the general rule is that "heavy" trucks enter the weigh lane and "light" trucks enter the passing lane. This sorting is done by the drivers themselves and therefore depends, to a large extent, on the honesty of the truck drivers. Some enforcement of this honour rule is done by the inspectors who may order a "heavy" truck in the passing lane to move into the weigh lane.

However, available data shows that in general, this apparent sorting of trucks is ineffective as a pre-screening method for potential weight infractions. In other words the weight infraction rate for trucks in the weigh lane is not higher than the infraction rate for all trucks approaching the station (See Section 4).

At stations with high truck flows, trucks will use the passing lane to avoid excessive delays if the queue lengths in the weigh lane become too long.

The diversion of trucks from the weigh lane to the passing lane is shown in Figure 5 which is based on data from a station having an average hourly truck flow in excess of 300 trucks/h. Figure 5 shows that the proportion of trucks entering the weigh lane varies according to the number of trucks entering the station. When the truck flow is three or less trucks/min., 39% of trucks enter the weigh lane. However, as the truck flow increases, the proportion of trucks entering the weigh lane decreases, until an equilibrium is reached at a truck flow of 6/min.

3.2.2/ Weigh Lane Operation

Trucks entering the weigh lane are weighed and the axle weights recorded by the inspector inside the station building. The inspector has control over signals which give the truck drivers instructions to advance and

stop. Using these signals the operator directs the driver so that each axle combination can be weighed separately. (See Figures 6 and 7). On the long platform scale the whole truck is weighed; however, this type of scale has not produced any saving in weighing time and is not employed at many stations.

Usually, every truck that enters the weigh lane is weighed, except for the rare occasion an obviously empty truck enters the weigh lane.

In addition, other non-weight stationary inspections may be completed in the weigh lane. In the case of a multi-man station, an inspector other than the one operating the scale, if available, will perform the non-weight inspections. This may involve inspecting documents and/or commodities carried. In the case of a one-man station the inspector will leave the weigh scale controls and perform non-weight inspections.

Thus far it has been implied that the weigh lane operation is similar for all types of stations, except for low volume stations with only one inspector. However, when a weight infraction is detected, there are significant differences in the operation of the weigh lane or the various types of stations.

3.2.2.1/ Straight Layout Stations

In this type of station, the actions taken when a weight infraction is detected appear to depend on the truck volume entering the station. For example, where truck volumes are approximately 300 trucks/h, when a weight infraction is detected, the scale operator closes the station, clears trucks queuing in the weigh and passing lanes and then proceeds to reweigh the truck.

At stations where the intensity of truck flow is not as high, the station is not normally closed if a weight infraction is detected. Instead the scale operator switches on the green ("leave") signal, thus indicating to trucks entering the station that they can proceed through the station without stopping to be inspected. This procedure is also adopted at stations without automatic signs to indicate whether the station is open or closed.

3.2.2.2/Racetrack Layout Stations

As described earlier, because this type of station has a driveway around the back of the station, truck re-weighs can be performed without interfering with the operation of the weigh and passing lanes.

In addition to the weighing operation, the weigh scale operator can perform visual inspections as the trucks move through the weigh lane. These include: physical defects and lighting, license plates, PVC plates, owner's name on vehicle, and physical dimensions of the load.

Since these checks can be done by the scale operator as he guides the trucks onto the scales, no additional time is required to perform them.

In addition, stationary non-weight checks are made in the weigh lane, on selected trucks.

3.2.3/ Weight Adjustments

Often, if a weight infraction is detected, the inspector will allow the driver to adjust the distribution of weights on the axles by adjusting the axle location, changing the position of the fifth wheel, or by redistributing the load on the truck. Normally the truck driver will not be charged if he can comply with the weight regulations by performing these adjustments.

These adjustments disrupt the weigh lane operation, since one or more re-weighs may be required, necessitating the closing of the station until the weight adjustments are completed. These adjustments can result in the station being closed for a significant proportion of the shift if they occur frequently.

3.2.4/ Passing Lane Operation

This lane allows trucks to bypass the weigh scale. If there are no inspectors in the passing lane, trucks drive through and exit from the station. A truck may slow down or stop briefly adjacent to the station building to get confirmation from the inspector in the building that it is free to leave the station.

If an inspector is available he may:

- wave the truck through, since in his judgement no stationary inspection is necessary;

- stop the truck for a stationary inspection. (If the inspection is complicated and time-consuming the inspector may ask the driver to park his truck and bring his papers to the station building);

- ask the driver to park the truck and come to the station building where the inspector will process the infraction;

- request the truck to enter the weigh lane if the inspector suspects that the driver is using the passing lane to avoid detection of an overload;

- ask the driver to park the truck and secure the load. (The driver may be charged if the law has been violated.)

The station staff (Highway Carrier Inspectors) inspect trucks visually for any gross mechanical defects as the trucks pass through either lane.

3.2.5/ Mechanical Inspections

These checks refer to the thorough mechanical checks performed by a team of mechanical inspectors, as opposed to the cursory visual checks performed by the station staff. The standard form used for these inspections is shown in Figure 9.

The normal practice is for the mechanical inspectors to select trucks for inspection from the weigh or passing lanes. The trucks are parked and a standard mechanical examination of 15 to 20 minutes duration is performed. The truck may than either:

- be released with no charge,
- charged and released,
- charged and detained until the mechanical fault is corrected, or
- escorted or towed to a service station.

The mechanical inspection does not significantly interfere with the normal operations of the station, except that it makes additional demands on the parking areas.

3.2.6/ Infraction Processing

Infractions can be categorized in two main groups: weight and non-weight infractions.

3.2.6.1/ Weight Infractions

If an overload is detected, the truck is carefully re-weighed and the axle weights recorded by the inspector operating the scale at the time the infraction was detected. The same inspector then becomes involved in the processing of the infraction since this simplifies giving evidence before the courts if required.

After the re-weigh, if the inspector decides to lay a charge (as opposed to giving a warning), the truck driver is requested to park, and the distances between the axles are measured. If only one staff member is available to measure the axles, either the truck driver will assist in the axle measurement, or a mechanical device can be used so that an inspector can take the axle measurements alone. (See Figure 8.)

The driver is then requested to bring his documents to the station building, where the charge is written up by the inspector. The driver's documents may be checked and further charges laid if non-weight infractions are detected. After charging, the truck may be released or detained depending on the seriousness of the infraction. In the latter case the truck may have to be off-loaded.

3.2.6.2/ Non-Weight Infractions

If a non-weight infraction is detected, the driver is asked to park the truck and to bring his documents into the station building. The inspector then writes up the charge and may check with other agencies to verify certain documents. After the charge has been written up, the truck is either released or detained.

3.2.7/ Truck Impounding

For "serious" infractions the truck may be impounded after charging, until the infraction can be corrected (e.g., off-loading some of the cargo onto a second truck, or repairing a serious mechanical defect).

4/ DATA ANALYSIS OF EXISTING OPERATIONS

During the study a data collection program was undertaken and the findings documented in detail in a separate confidential report [6].

The purpose of the data collection program was to:

- observe in detail the operation of different stations in order to develop a simulation model that would account for the variations in operation of the different types of stations;
- obtain data to be used as input for the simulation model; and
- obtain data that could be used to compare with the simulation model output in order to validate the model;

Data were collected from 10 different stations across the province, representing a cross-section of stations in use.

This section summarizes data collected in this study and from other studies, and describes how the data was rationalized for use as input to the simulation model.

4.1/ Hourly Truck Flows

Twenty-four hour vehicle counts taken by the Ministry at five stations were used to determine the average day and night truck flows on the adjacent highway.

Figure 11 shows the 24-hour variations in truck flow on highways adjacent to four stations. In addition, the average truck volume throughout a 12 hour day-time and night-time period is also indicated.

Where 24-hour counts were unavailable, the average hourly truck flows collected during the Data Collection phase were used for the day-time shifts. Night-time shift average hourly truck flows were estimated from the ratios of available night shift to day shift hourly flows at similar stations.

4.2/ Stationary Weight Inspection Times

4.2.1/ First Weighing Times

These are variable, largely depending on the type of truck being weighed. For example a double-axle truck takes less time to weigh than an eight-axle truck.

Data collected at high volume stations showed the (average) weighing time for all trucks to be approximately 35 s.

These data were analyzed further and found to have a skewed distribution as shown in Figure 12. This skewed distribution was reproduced to simulate the random variations in weighing times.

4.2.2/ Re-Weigh Times (Second Weighing)

Data collected showed this operation could take from 1 to 24 min, with an average time of 5 min. For simulation purposes an average of 5 min has been assumed for all stations, except for those with racetrack layouts, where a re-weigh time of 1.5 min was assumed.

A single value for re-weighing time has been used (5 or 1.5 min, depending on the station layout) because the relatively rare occurrence of re-weighs would require excessive computer processing time to establish convergence between the actual and simulated mean re-weigh times.

4.2.3/ Percentage of Re-Weighed Trucks Charged

Collected data showed that 45% of re-weighed trucks were charged. Overloaded trucks may not be charged if they can conform to the weight regulations by adjusting the loads and/or air axles, or if the severity of the overload warrants only a warning.

It was assumed that 50% of the trucks that are reweighed are not charged except at Stations C and F where a higher percentage of charges are laid. At these stations most of the overloads were aggregate and wood trucks respectively, the loads of which cannot be easily redistributed to comply with the weight regulations. In order to account for trucks that are re-weighed and not charged, the weight infraction rate is adjusted in the simulation input. For example, 5% weight infraction rate is input as a

10% weight infraction rate to account for the 50% of infractions that are not charged.

4.3/ Stationary Non-Weight Inspection Times

Data collected from stations indicate the time taken for non-weight inspections ranges from 4 s to 845 s (14 min). Also the average, and distribution of, times varied from station to station. These variations are due to:

- the attitude of the inspectors at different stations as to what they perceive to be a thorough inspection;
- the truck population entering the station;
- some trucks being inspected in the inspection lane whereas others are inspected in the parking area; and
- the small data samples obtained at some stations.

Non-weight inspection times from all stations were aggregated and the frequency distribution is shown in Figure 12. This distribution was used to simulate the random variation in non-weight stationary inspection times.

4.4/ Parking

Parking capacity is the maximum number of trucks that can be parked in the station. Capacity data was obtained from station plans and inspectors' interviews. Parking spaces may be used by trucks undergoing mechanical inspections, extended non-weight inspections or while waiting for an infraction to be processed.

During shifts where mechanical inspectors are available, two additional parking spaces are usually required to allow each person in a two-man mechanical vehicle inspection crew to examine one truck.

4.5/ Queue Lengths

4.5.1/ Maximum Possible Queue Length

This is the maximum number of trucks that can be stored between the weigh

house and the station entrance before trucks back onto the highway and the station is forced to close. This was calculated from station plans, assuming 15m (50 feet) of storage space per truck.

4.5.2/ Maximum Queue Length in Weigh Lane Before Trucks Divert to Passing Lane

In the higher volume stations queues build up in the weigh lane, and at some point trucks start moving to the passing lane to avoid the queuing delay and/or to avoid an overload detection. Based on discussions with station supervisors, this has been assumed to occur when the queue contains 4 or more trucks.

4.6/ Infractions

The following discussion is based on data collected in a previous study [2]. It should be noted that the data is temporal and subject to large variations and therefore many of the inferences may be speculative.

Infractions have been categorized into weight and non-weight infractions.

4.6.1/ Weight Infraction Rates

During the summer of 1980 special surveys were done at various stations in order to determine the infraction rates for trucks on the highways adjacent to the stations. These surveys utilized random sampling of trucks in which every n^{th} truck entering the station was given a thorough inspection. This method of inspection differs from the regular shifts where the inspectors appear to be selective as to which trucks are to be inspected. One would therefore expect the infraction detection rate to be higher during regular shifts as compared to the special random surveys. For example, if inspectors inspected trucks on a random basis, one would expect the infraction detection rate to be the same for regular shifts as compared to the special surveys. However, if inspectors could introduce a bias, where they only weigh trucks which appear to be "heavy", then the weight infraction detection rate should be higher than for random inspections.

Table 1 is a comparison of infraction detection rates for regular shifts and special surveys during 1980. Column 1 shows weight infraction rates for random sampling completed during special surveys in the summer of 1980. Column 2 shows the weight infraction rates for regular shifts. Column 3 is the percentage of infractions detected. Column 4 shows the percentage of trucks entering the station which were inspected for weight, based on one day's observation during the data collection phase of this study. Column 5 shows the percentage of trucks on the adjacent highway that were inspected for weight infractions. These values were obtained by adjusting the values in Column 4 for trucks that bypassed the station due to shutdowns.

The data shown in Table 1 is difficult to interpret since some of it supports the hypothesis that inspectors are able to screen trucks for inspection, thus increasing the probability of detection of infractions compared to random inspections. For example, data for Stations B and D support this hypothesis, in that 61% and 74% of weight infractions were detected by inspecting 29% and 36% of the trucks respectively.

On the other hand, data for Stations A and H indicates that the percentage of weight infractions detected during regular shifts is lower than obtained from random inspections. This may suggest that overloaded trucks use the passing lane to avoid the weigh scales.

Another explanation may be that during regular shifts the inspectors judge the truck axle spacing visually. Since weight infractions are determined by both the axle load and axle spacing, some weight infractions may not be detected due to errors in judging the axle spacing.

It could be speculated that effective screening is only possible at low volume stations. Figure 13 is a graph of infraction detection efficiency plotted against truck volumes at various stations, and indicates that there is no apparent relationship between infraction detection efficiency and truck volume.

Therefore, based on the available data, it is assumed that, in general, there is no effective method of pre-screening trucks for weight inspections using current techniques. In order to simulate this in the computer

model, it has been necessary to assume that trucks enter the weigh lane on a first come, first served basis, and trucks using the passing lane do so to avoid delays due to long queues in the weigh lane.

4.6.2/ Non-Weight Infractions

Table 2 shows the detection efficiency for non-weight infractions. Except for Stations D and E, screening for infractions appears to be effective. For example, at Station G stationary non-weight inspections of 5% of the trucks resulted in 28% of the non-weight infractions being detected.

One possible explanation of the apparent greater success in screening for non-weight infractions is that a stationary non-weight inspection can be done in both the weigh or passing lane. However, a stationary weight inspection can only be done in the weigh lane.

Although the station inspectors try to ensure that "heavy" trucks enter the weigh lane it would be in the interests of the driver, who is knowingly over-weight, always to try to use the passing lane because in using the weigh lane it is certain the overload will be detected. In using the passing lane his chances are better in that there is a possibility that he will not be asked to move over into the weigh lane. Since overloaded trucks often only constitute 1% to 2% of the total trucks entering a station, this bias of drivers who are knowingly overloaded "taking their chances" in the passing lane could have a significant effect on the weight infraction detection efficiency of a station.

However, for simulation purposes it is assumed that there is no effective method of pre-screening trucks for non-weight inspection because of the relatively "sketchy" data.

4.6.3/ Ratio of Non-Weight to Weight Infractions

In order to assess the impact of infraction rates on a "typical" station operation, not only the total infraction rate (weight and non-weight) but also the types of infractions are required as input, since weight and non-weight infractions are processed differently. Since there is an infinite number of combinations of weight and non-weight infraction rates that could be assessed, it has been necessary to aggregate the data in

order to arrive at an average ratio of non-weight to weight infractions. Based on the data shown in Table 3, the aggregate ratio for "typical" stations is approximately two. This ratio has been used for the simulations in Section 7. In the simulations of individual stations in Section 9, the rates for weight and non-weight infractions shown in Table 3 have been used.

4.6.4/ Infraction Processing Time

Average times are used rather than a distribution because these are rare events compared to truck arrivals and stationary inspections. In not using a distribution of times, the necessity of very long computer simulation runs to allow convergence between actual and simulated means can be avoided.

The average time to process a weight and non-weight infraction was found to be 15 and 25 min respectively.

4.7/ Operating Costs

Operating costs of stations consist of three components: capital costs, maintenance costs and salaries. Data for these components were supplied by the Ministry. The operating costs were used to determine unit costs for various types of inspections at selected stations.

4.7.1/ Capital Costs

Table 4 summarizes the capital costs for the various stations. Average construction costs have been assumed for the various types of stations. These costs could vary significantly depending on local site conditions and other factors. Also, interest rates can vary, and therefore the costs shown are only indicative.

4.7.2/ Maintenance, Electricity and Water Costs

These costs vary from year to year, therefore an average cost was determined from the available data as shown in Table 5. Costs shown exclude depreciation, telephone, and taxes.

4.7.3/ Salaries

Table 6 summarizes the 1980 salary costs for the various stations assuming that the stations are open throughout the year.

4.7.4/ Total Costs

The total cost of operating a station is the sum of the capital, maintenance and salary costs. These are shown in Table 6 and, as mentioned previously, the costs are indicative only.

4.8/ Truck Delays

Data were collected representing the delay to trucks passing through stations when there was no queuing or inspection delays.

4.8.1/ Delays to Trucks Using One-Way Stations

The total delay consists of the following components:

- deceleration from the posted highway speed to a virtual stop at the weigh house when entering the station, and
- acceleration from a virtual standstill at the weigh house to the highway posted speed when leaving the station.

These delays are shown in Table 7.

4.8.2/ Delays to Trucks Using Two-Way Stations

In this type of station, the manner in which trucks enter is different depending on whether the trucks enter from the lane adjacent to the station or the opposing lane. In the former case, the trucks enter via a ramp in a similar manner to that of a one-way station. Trucks using the opposing lane must slow down or stop opposite the station entrance and then execute a left turn to enter the station.

Trucks exiting the station drive from the weigh house to the stop sign at the station exit, and then make a left or right turn onto the highway.

Therefore the total delays to trucks entering from the lane adjacent to the station consist of the following components:

- deceleration from the posted highway speed to a virtual stop at the weigh house when entering the station;
- driving from the weigh house to the stop sign at the station exit; and

- acceleration from the stop sign at the station exit to the posted highway speed.

The total delay to trucks entering the station from the opposing lane consists of the following components:

- deceleration from the highway posted speed to make the left turn opposite the entrance to the station;
- execution of the left turn and driving up to the weigh scale;
- driving from the weigh house to the stop sign at the exit to the station; and
- acceleration from the stop sign at the station exit to the highway posted speed.

These delays are shown in Table 8.

4.8.3/ Determination of Delay Components

The components of the total delays to trucks driving in and out of stations with no inspection have been calculated based on data collected in the field, data obtained from a computer simulation program and plans of station layouts.

4.8.3.1/ Deceleration from the Highway Operating Speed to a Virtual Stop at the Weigh House when Entering the Station.

Data collected at the Station F showed that the average time taken for a truck to drive from a point 1 km from the station entrance to the weigh house was 79 s. Similar data were collected at another station and the average time taken was 46 s.

This large difference in times is probably due to the fact that most of the trucks at station F were heavily laden wood trucks.

Therefore, the delay decelerating into the station is the time taken for trucks to drive from the 1 km sign to the weigh scale in the station, minus the time taken to cover the equivalent distance along the adjacent highway at the posted speed. Table 9 shows the delays decelerating into selected stations.

4.8.3.2/ Acceleration from Weigh House to Highway Posted Speed

The time and distance taken for trucks to accelerate from a standstill to various speeds were calculated using a simulation model [8].

The difference between the time taken to accelerate to the posted highway speed and time taken to cover the same acceleration distance at the posted highway speed, is the delay to trucks.

4.8.3.3/ Driving from the Weigh House to the Stop Sign at the Station Exit (Two-Way Stations Only)

Data collected at Station F showed that average time taken was 22 s. These data were used for stations with similar layouts.

Similar data collected at Station I showed this delay to be about 40 s. This difference is due to the layout of the station.

4.8.3.4/ Deceleration from Highway Posted Speed to Make Left Turn Opposite the Station Entrance (Two-Way Stations Only)

Trucks timed at Station F showed an average of 53 s from the 1 km sign to the point where trucks were ready to execute the left turn.

$$\text{Therefore the delay involved} = 53 - \frac{(1.0 \text{ km} \times 3600 \text{ s})}{90 \text{ km/h}}$$

$$= 13 \text{ s}$$

4.8.3.5/ Executing the Left Turn and Driving Up to the Weigh House (Two-Way Stations Only)

Trucks timed at Station I showed that this manoeuver took an average of about 15 s.

Note: Timing for trucks at Station F should be representative of most other two-way stations since very few wood trucks enter the station from the east end. However, trucks timed at Station I took about 40 s to cover the distance to and from the weigh house to the highway. This is due to layout of the station which has a long approach to the weigh house with small radii.

4.8.4/ Total Delay

The total delays to trucks at the various stations (excluding queuing and inspection time) were calculated by adding the components described in (4.8.3). This is shown in Tables 7 and 8 for two-way and one-way layout stations respectively.

This is summarized below:

- Station A 67 s
- Station B 61 s
- Station C 61 s
- Station D 61 s
- Station E 61 s
- Station F 95 s
- Station G 128 s
- Station H 61 s
- Station I 73 s
- Station J 46 s

PART C

SIMULATION MODEL DEVELOPMENT

5/ TRANSFORMING STATION OPERATIONS INTO A SIMULATION MODEL

In order to transform the station operations as described in Section 3 into a simulation model, the operations must be described in a very tight logical structure. Therefore this section describes how the various operations of the station and their interactions are broken down into logic sequences. Flow charts have been used to describe this where possible. For simplicity of description the simulation model has been subdivided into separate portions with a separate flow chart describing each portion of the model. The separate portions are interrelated as shown in Figure 14. A complete detailed flow chart of the simulation model is contained in the back cover pocket.

The process of describing the operation of stations in a logical structure illustrates the principles used in the simulation and provides useful insights into the station operations.

This section is generally related to multi-man stations since these are operationally more complex. The differences in simulation as applied to one-man stations are also described.

The purpose of the simulation model is to determine the (feasible) levels of enforcement under certain constraints, using inputs that are based on averaged field data, station layout, crew size and a fixed inspection procedure. Therefore it is possible that the simulation outputs could vary significantly from field data depending on the attitudes and perceptions of inspectors and the truck population using the stations.

Therefore, a good understanding of the conditions at a particular station is required in order to rationalize any differences between simulation output and field data. This is done in Section 9, where simulation output is compared with field data for specific stations.

5.1/ General Concept of the Station Operation

Figure 15 is a simplified diagrammatic representation of possible events at a station during a work shift. This representation is described below.

Trucks approaching a station during a work shift contain both infractors and non-infractors. When the station is closed down for reasons mentioned previously, a proportion of the trucks do not enter the station and some of the infractions are not detected. This is likely to occur at high and medium volume stations and less often at low volume stations.

The rest of the trucks enter the station, a certain proportion not being fully inspected because of inadequate facilities or manpower resources and, again, some infractions are not detected. Of the trucks that are inspected adequately, a certain number of infractions are detected and charged. These charges are recorded as statistics.

Consequently, the percentage of infractions detected at a station is not a true reflection of the percentage of infractions on the adjacent highway. This is shown in Table 10.

Therefore part of the simulation process estimates the number of trucks that:

- do not enter the station during temporary closures,
- enter the station but are inadequately inspected,
- enter the station and are adequately inspected, and
- have detected and undetected infractions.

5.2/ Truck Flow Approaching a Station

This portion of the model simulates the flow of trucks on the highway and the characteristics of the truck population within that flow.

5.2.1/ Truck Flow

Although the average traffic flow on a highway may be constant over a certain period, say 300/h, the arrival of traffic within a short time period will be random. This is simulated by generating a set of random numbers representing truck arrivals. The set of random numbers has a mean equal to the average arrival rate of trucks at a particular station. For example, a truck flow of 300 trucks/h would be represented by a random set of numbers with a mean arrival rate of 5 trucks/min.

5.2.2/ Truck Population Characteristics

The characteristics of the trucks entering a station will determine the sequence of operations within the station on arrival. For example, if a truck with a weight infraction enters a straight layout station and the infraction is detected, the weigh lane will be closed down to re-weigh the truck and the infraction will be processed. On the other hand a truck with no infraction will be waved on after inspection.

Therefore trucks approaching a station can be subdivided into three categories:

- trucks with no infractions,
- trucks with weight infractions, and
- trucks with non-weight infractions.

The various types of infractions are assumed to be randomly distributed in the overall truck population.

Therefore the input for this portion of the simulation model comprises:

- the average rate of truck arrivals,
- the percentage of trucks with weight infractions, and
- the percentage of trucks with non-weight infractions.

5.3/ Processing of Trucks Through a Station Under Uninterrupted Flow

The concept of uninterrupted flow is used to describe the operation of a station with no interruptions due to infractions or re-weighs and no temporary closures due to excessive queue lengths. Uninterrupted flow represents the "ideal" condition where there is 100% compliance.

Figure 16 is a flow chart of a station operating under uninterrupted conditions, and indicates the possible types of inspection that can take place in the station under these conditions.

As can be seen from the flow chart in Figure 16, the following four types of inspections are possible:

- **Type 1** This type of inspection takes place in the passing lane. The truck drives through the station without being weighed or stopped for a non-weight inspection. Since this type of inspection is a moving inspection, only gross visible infractions may be detected (e.g. missing licence plates, gross mechanical or safety defects, excessive height).

- **Type 2** This type of inspection takes place in the weigh lane. The truck is weighed and other stationary non-weight inspections performed (e.g. bills of lading, drivers licence, and operating permits are inspected).

- **Type 3** This type of inspection takes place in the passing lane and is a stationary non-weight inspection similar to that described for Type 2 inspections.

- **Type 4** This type of inspection takes place in the weigh lane. The truck is weighed but no stationary non-weight inspections are done. The truck is weighed and then released from the station.

The above four types of inspections are summarized in the chart in Figure 17.

However, stations rarely operate under uninterrupted conditions. The uninterrupted operation ceases when one, or more, of the following occurs:

- when a weight infraction is detected in the case of straight layout stations,
- when all the staff are occupied processing infractions,
- when queue lengths in the station become too long with the possibility of trucks backing onto the adjacent highway, or
- when parking space is not available.

The above occurrences may result in temporary closure of the station.

5.4/ Station Closures

Closures result in trucks not entering the station so that inspection of trucks is not possible. These closures reduce the efficiency of the station with respect to enforcement and allow infractions to go undetected.

To simulate these situations in the computer model, queue lengths, staff availability, and parking availability are constantly monitored. When any of the parameters for the above factors are exceeded, the station closes. The computer model accounts for the number of trucks not entering the station during the closures and records the number of probable infractions that go undetected. This is illustrated by the flow chart shown in Figure 18. As the events causing closure clear, the station reopens.

As mentioned previously, a straight layout station may close temporarily when a weight infraction is detected so that the truck may be reweighed. These closures are described in Section 5.6.

5.5/ Sorting of Trucks into the Weigh and Passing Lanes

Section 3.2 describes how trucks are apparently assigned to the weigh and passing lanes, and this would imply that this may be a pre-screening process for weight infractions.

Since this apparent pre-screening process appears to be ineffective, it was assumed for simulation purposes, that there is no pre-screening of trucks with respect to their assignment to the weigh or passing lanes at existing stations.

The method by which trucks are assigned to the weigh or passing lane under existing conditions is shown in the flow chart in Figure 19. With this method trucks are assigned to the passing lane only if the number of trucks queuing in the weigh lane exceeds a certain value. If the truck queue builds up in the passing lane and exceeds that of the weigh lane queue trucks, trucks are pre-assigned to the weigh lane.

However, a provision for the pre-screening of trucks has been made in the simulation model. This option can be used to assess the advantages of an effective pre-screening technique which may be developed in the future, such as the use of weigh-in-motion or sorter scales. This is discussed later, in Section 8.7.

5.6/ Weigh Lane Operation

The operation, described in Section 3.2.2, can be described for simulation purposes using the flow chart shown in Figure 20. The following numbers in parentheses refer to the numbers on the flow chart.

The number of trucks in the weigh lane queue is monitored (1), and if this queue becomes excessive the station may have to close temporarily.

If an inspector is available for a non-weight inspection (2), the truck will have a stationary non-weight inspection (3) and will then be weighed (4). If an inspector is not available for a stationary non-weight inspection the truck will be weighed only.

After weighing, if there is no weight infraction (5), depending on whether the non-weight inspection is complete (6), the truck will either be released (7) or parked so the non-weight inspection can be completed (8). If there is a weight infraction (5), depending on the type of station (9), there are two possible sequences. In the case of a racetrack layout station, the truck is sent around the weigh house (13) and re-enters the weigh lane (14) and is re-weighed (15). In the case of a straight layout station, either the station or weigh lane is closed, depending on the volumes of trucks entering the station, and the queues of trucks in the station cleared (11) so that the truck can back-up for a re-weigh (15).

In many cases, weight regulations may be met by redistributing the axle loads through adjustments to the air axles, and the inspector may or may not charge the infractor (16). If no charge is laid, the truck is released (7) or, if a charge is to be laid, the infraction paper work is processed (17). After the infraction has been processed, the inspector

again becomes available for inspections (18) and the truck is either released or detained (19).

Non-weight infractions are processed in a similar manner.

The simplified flow chart (Figure 21) indicates the interaction between the type of inspections that can be performed in the weigh lane and the availability of inspectors.

The inputs required for this portion of the simulation model are:

- the type of station,
- first weighing times for trucks,
- re-weighing times,
- time taken to perform a stationary non-weight inspection, and
- the time taken to process a weight infraction.

5.7/ Passing Lane Operation

The operation of this lane is less complex since only stationary non-weight inspections are performed here. A flow chart for this operation is shown in Figure 21. The numbers in parentheses refer to the numbers on the flow chart.

The number of trucks in the passing lane queue is monitored (1) and, if this queue becomes excessive, the station may have to close temporarily. Trucks are either released if no inspector is available (3), or inspected (4) if an inspector is available.

After the non-weight inspection, the truck may be released if there is no infraction (5), or if an infraction is detected the infraction is processed (6).

After processing of the infraction the truck is either released or detained (9) and the inspector again becomes available for inspections (7).

In the simulation model provision is made for the inspector to request the driver to park the truck if the stationary inspection will exceed a

certain time period (e.g. 2 min). This is not shown in the flow chart in Figure 21 in order to maintain its simplicity.

The input required for this portion of the simulation model is:

- time taken to perform a stationary non-weight inspection,
- the delay for trucks passing through with no stationary inspection (i.e. stopping or slowing down at weigh house for approval to leave the station), and
- the maximum stationary inspection time before the inspector will request the truck to park in order to complete the inspection.

5.8/ Staff Allocation

As can be seen from the flow charts for the weigh and passing lane operations, the types of inspection that can be performed depends on the availability of staff. In extreme cases, when all the staff are occupied processing infractions, the station will close temporarily. In less extreme cases there may not be sufficient staff to perform stationary non-weight inspections and the only possible type of inspection may be a moving inspection. Both situations will reduce the thoroughness of the inspection process and increase undetected infractions.

The flow chart in Figure 22 shows how this is simulated in the model and is based on the following assumptions.

- All inspectors duties are interchangeable and form part of a staff pool. For example if the inspector operating the weigh scale detects an infraction which has to be processed, another inspector, if available, will take over the weigh scales while the infraction is being processed.

- The weigh scale operation has priority. For example if only one inspector is available he will operate the weigh scale rather than leaving the weigh scale to perform non-weight stationary inspections.

The following describes the flow chart in Figure 22. The numbers in parentheses refer to the numbers on the flow chart.

First there is a check to see if the weigh scale is manned (1). If it is not manned there is a check to see whether there is an inspector in the staff pool to man it (2). If nobody is available the station is closed (3), or if an inspector is available he is assigned to the weigh scale (4).

If the weigh scale is manned (1) there is a check for staff to perform non-weight stationary inspections (5). If staff is not available trucks pass through the station with only moving non-weight inspections (6). If staff is available they are assigned to performing stationary non-weight inspections on selected trucks (7).

An inspector at the weigh scale remains there until an infraction is detected (8). When an infraction is detected, the inspector leaves the weigh scale to process the infraction (9). When the processing is completed (10) the inspector returns to the staff pool (13) and is re-assigned to some other inspection duty.

Similarly, an inspector performing non-weight stationary inspections is assigned to this duty until an infraction is detected (11). When an infraction is detected, the inspector leaves this duty to process the infraction (12). When the processing is completed (10), the inspector returns to the staff pool (13) and is re-assigned to some other inspection duty.

In the case of a one-man station, the staff allocation portion of the program is suppressed. Also, the station remains open if the scale is unmanned in the case where the inspector has to leave the weigh house for a non-weight inspection.

The input for this part of the simulation model would be the number of inspectors operating the station.

5.9/ Parking Capacity

Parking availability is monitored constantly during the simulation and the station may close if the limit is exceeded.

5.10/ Mechanical Inspections

As described in Section 3, these are done by a separate crew of inspectors. This operation does not form an integral part of the station operation, and is therefore not included in the simulation model. However, the effect of mechanical inspectors at a station can be simulated by reducing the available parking space (usually 2 spaces) by the number of inspectors on duty.

5.11/ Other Inspections

Inspections by other agencies, such as gasoline/diesel fuel taxes and exhaust emissions, can be simulated by reducing the available parking space as described in 5.10.

6/ VALIDATION OF THE MODEL

Once the computer simulation model had been developed, it was necessary to test the model in order to assess the validity of the output before it could be used to study the performance of the stations.

Three approaches were used in order to validate the model.

6.1/ Scrutiny of Output

The model's output was scrutinized to see if it was sensible and conformed to intuitive expectations. For example, if the average weighing time was increased by 10 s, one would expect the average delay to trucks to increase by more than 10 s, and the sum of detected and undetected infractions to approximate the percentage of infractions input to the model, etc. In the cases where the output deviated from intuitive expectations and could not be logically explained, the model was investigated to detect and correct the error. These investigations are too numerous to describe in this report; however, the scrutiny of the model's output was a continuing process throughout the study.

6.2/ Testing the Stochastical Nature of the Model

As described earlier in this report, the operation of a station is stochastical because of the random arrivals of trucks and the random time periods required to perform the various types of inspections. It was therefore important to verify the model's ability to simulate this stochastical behaviour, since this may lead to temporary overloading of stations.

Therefore-data on the stochastical behaviour of station operations were collected by recording such things as queue length and passage of trucks through the station on a minute to minute basis. This was compared with the simulated minute by minute output from the computer model.

As can be seen from Tables 11 and 12 there is a good correlation between the field data and simulated output.

6.3/ Simulating a Complete Shift at a Station

A complete shift was simulated with the computer model and compared with the data collected from one complete shift at Station E (see Table 13). The infraction rate of the approaching truck population was determined from the detected infraction rate observed in the field, because the infraction rates for the truck population on the highway for that particular day were not known. This manipulation of the infraction rates produced an estimate of the infraction rates of the actual truck population approaching Station E for the specific day on which the data were collected. This was done by increasing the infraction rates for the truck population until the detected infractions, as predicted by the simulation model, were approximately equal to the field observations. The total infraction rate estimated by this procedure was 2.8%, which compares favourably with the 2.9% average infraction rate established in the Truck Compliance Rates Study [2].

It should be noted that the computer simulation described in this section was to simulate one unique shift at Station E. The simulation described in Section 9 is for an average shift and therefore uses different input data, resulting in different output reflecting the average expected behaviour of the station.

PART D

GENERAL PRINCIPLES OF STATION EFFICIENCY

7/ SIMULATIONS OF "TYPICAL" STATIONS

Although each station is unique, there are common factors which make it possible to simulate "typical" operations for the different station lay-outs.

Although these "typical" stations do not take into account some of the unique features of each station, such as the different "styles" of operation by the staff, and the different compositions of the truck population, the "typical" simulations do provide good insight into general principles for the efficiency of operation of stations with respect to:

- layout,
- truck volume,
- infraction rates,
- manpower levels, and
- weighing time.

In order to account for the uniqueness of individual stations, eight specific stations have been simulated individually in Section 9, and compared with the "typical" simulations developed in this section.

7.1/ Weigh Lane Operation

The weigh lane operation was simulated as a separate operation to gain some insight into the weight enforcement component of truck inspection stations. Two aspects were investigated: the effect of different average weighing times and the effect of diverting trucks to the passing lane. The simulations assumed no other inspections are done in the weigh lane and no interruptions due to infractions.

7.1.1/ Weighing Times

Charts A and B in Figure 23 show the effects on queuing and delays for different average weighing times and truck flows. It is assumed that no trucks divert to the passing lane.

The average weighing times shown were assumed to have a 20 s range and a uniform distribution. For example, the 20 s average weighing time has a range of 10 to 30 s. These distributions were assumed since there is no indication of the types of distributions for weighing times should the present weighing methods be altered.

The charts show that maximum number of trucks that can be weighed with an average weighing time of 30 s is 100 trucks/h, before the queues and delays start to approach infinity. Of particular note is the large reduction in delays to trucks if the average weighing time is reduced from 30 s to 20 s. At a flow of 100 trucks/h, the average delay is reduced from 100 s to 35 s. This indicates the potential of improving the efficiency of the weigh lane operation for large truck flows by reducing the average weighing time.

7.1.2/ Effect of Diverting Trucks to the Passing Lane

Charts A and B in Figure 24 are similar to those shown in Figure 23 except that the weighing time distribution shown in Figure 12 has been used in the simulation. The solid curves represent the weigh lane operation where the trucks do not divert to the passing lane, and the broken curves represent operations when trucks are permitted to divert to the passing lane if the weigh lane queue reaches four trucks. (See Section 4.5).

In the former case, the weigh lane truck queue and delays start to approach infinity at a flow of 100 trucks/h.

In the latter case, the truck queue and delays remain at acceptable limits for flows greater than 100 trucks/h.

The reasons for the increase in capacity of the weigh lane when the queue length is restricted is that this prevents temporary overloading of the weigh lane due to the stochastical nature of truck arrivals and weighing times.

Therefore it appears that the efficiency of the weigh lane operation can be improved by limiting the queue length in the passing lane. (See Section 8.2 for further discussion of this point).

7.2/ Capacities of Stations for Uninterrupted Operation

The concept of uninterrupted operation has been used to assess the capacities of stations with no interruptions due to infractions. Under these conditions all multi-men stations can be considered to be the same, since the difference in operation between a straight layout station and a race-track layout station is the manner in which trucks with weight infractions are re-weighed.

In order to determine the capacity of a station the following approach has been taken. A series of simulations was made, in which it was assumed that all trucks entering the station require both stationary weight and non-weight inspections (Type 2 inspections). Figure 25 indicates what happens in a station when the volumes are high enough that processing facilities are exceeded for Type 2 inspections.

The capital letters shown in parentheses for the following description refer to the capital letters shown on the diagram in Figure 25.

All trucks entering the station (A) are potential candidates for a complete inspection. When the weigh lane reaches capacity (B), as determined by the queue length, trucks divert into the passing lane (C).

In the weigh lane a certain proportion of trucks may have only a stationary weight inspection (D) because an inspector is not available for a stationary non-weight inspection. Another proportion of the trucks in the weigh lane will have both a stationary weight and non-weight inspection (E) due to the availability of an inspector while the truck was in the weigh lane.

Similarly, of the trucks that divert to the passing lane, a certain proportion will have a stationary non-weight inspection (F) if an inspector is available for such an inspection.

The rest of the trucks (G) will have no stationary inspection since no inspector is available for this purpose during the trucks' passage through the passing lane.

Therefore, if factors such as weighing times and non-weight inspection times are constant, the operations within a station will reach some equilibrium where fixed proportions of the total trucks entering the station receive certain types of inspections. The fixed proportions of types of inspections are determined by the volume of trucks entering the station, and the crew size.

This equilibrium represents the MAXIMUM ENFORCEMENT LEVEL for a station with no interruptions due to infractions. This MAXIMUM ENFORCEMENT LEVEL has been determined according to the following parameters:

- no pre-screening of trucks for inspection;
- minimum queue length in weigh lane before truck drivers divert to passing lane — 4 trucks;
- minimum expectd time for stationary non-weight inspection in passing lane before driver is requested to park truck for inspection — 2 min;
- minimum queue length in passing lane before inspector clears passing lane without inspecting trucks — 4 trucks;
- maximum queue length in either lane before station closed due to excessive queue lengths — 10 trucks;
- inspection times — as shown in Figure 12.

7.2.1/ Effect of Varying Crew Size on the Level of Inspection

Charts A to E in Figure 26 show the capacities of a station for different crew sizes and represent the equilibria for MAXIMUM ENFORCEMENT LEVELS as

described previously. The types of inspections are as defined in Section 5.

7.2.1.1/ One-Man Crews

Chart A in Figure 26 shows the maximum level of enforcement for stations with a one-man crew. As can be seen, only Type 1 and 2 inspections can be performed if all trucks are suspect and require complete (Type 2) inspections.

The information in Chart A is interpreted as illustrated by the following example:

What is the maximum level of enforcement at a one-man station with a truck flow of 50 trucks/h, assuming interruptions due to infractions?

From Chart A it can be seen that at 50 trucks/h, 58% of the trucks will have complete (Type 2) inspections and 42% will have moving inspections (Type 1), or:

50 x 58/100	=	29	Type 2 inspections/h
50 x 42/100	=	21	Type 1 inspections/h
Total	:	50	

In the field the inspector may consider only a stationary weight inspection as adequate, so that Type 4 inspections are done (i.e., a method of pre-screening may be employed). However, this has not been assumed in the simulations since the available data indicate that this cannot be done reliably.

Although the percentage of fully inspected trucks (Type 2) decreases with increasing truck flow, the number of inspections remains constant. For example, at 100 trucks/h, 32% of the trucks are inspected, and at 200 trucks/h, 16% of the trucks are inspected. This shows that one-man stations can only process approximately 30 trucks/h under uninterrupted operating conditions.

7.2.1.2/ Multi-Man Crews

Charts B to E in Figure 26 show the maximum level of enforcement at

stations with multi-man crews. As can be seen, all four types of inspections are performed.

The information in Charts B to E is interpreted as illustrated by the following example.

What is the maximum level of enforcement at a three-man station with a truck flow of 200 trucks/h?

From Chart C it can be seen that at 200 trucks/h:

- 42% of the trucks have Type 2 inspections;
- 20% of the trucks have Type 4 inspections;
- 7% of the trucks have Type 3 inspections ; and
- 31% of the trucks have Type 1 inspections;

or

- 200 x 42/100 = 84 Type 2 inspections/h;
- 200 x 20/100 = 40 Type 4 inspections/h;
- 200 x 7/100 = 14 Type 3 inspections/h; and
- 200 x 31/100 = 62 Type 1 inspections/h.

Total : 200

The following salient observations can be made from Charts B to E.

- The number of trucks inspected in the weigh lane is constant for all crew sizes. For a truck flow of 400 trucks/h, 32% of the trucks (128 trucks/h) are inspected in the weigh lane, irrespective of crew size.

  However, as the crew size increases, the number of stationary non-weight inspections (Type 2) in the weigh lane increases from 9% with a two-man crew, to 20% with a five-man crew for the same truck flow (400 trucks/h).

- As crew size increases, the number of non-weight inspections increases in both the weigh and passing lanes, and the number of Type 1 inspections (moving inspections only) decreases.

- If there are no infractions a station can process up to 400 trucks/h with a negligible amount of trucks by-passing the station due to temporary closures. This indicates that temporary station closures are due to infractions rather than excessive queuing.

Chart A in Figure 27 shows the effect of crew size on the percentage of trucks that can be fully inspected (Type 2 inspections). For example, if an enforcement level of 50% Type 2 inspections is required, a flow of 200 trucks/h and a minimum crew size of four should be used.

Also, it is interesting to note that increasing a crew size from two men to three men produces the largest increase in the number of Type 2 inspections.

7.2.2/ Delays to Trucks

Chart B in Figure 27 shows the average delays to trucks for various crew sizes and hourly truck flows. The delays shown include the delays incurred in queuing for inspection, and the inspection delay. They do not include drive-through time. Therefore, the total average delay to a non-violating truck using a station would be the delay time shown in Chart B, plus the drive-through time given in Section 4, usually about 60 s.

It should be noted that trucks driving through a station with no stationary inspection are also included in determining the average delays.

The following salient observations can be made from Chart B.

- For a one-man crew, the average delays to trucks are much higher than multi-man crews for truck volumes below 100 trucks/h.

  Once the processing capacity of a one-man crew is reached at 30 trucks/h, the average delays start to reduce dramatically as the truck flow increases. The explanation for this is that Type 2 inspections are time consuming because the inspector first has to weigh the truck and then leave the weigh house to do a stationary non-weight inspection. However, once the handling capacity of the person is exceeded, the number of trucks clearing the station with only moving (Type 4) inspections increases and thus, the average delay to trucks decreases.

- For multi-man stations, delays to trucks increase as the crew size increases because the proportion of trucks with stationary inspections increases.

The average delay to trucks also increases with truck flow and reaches a maximum at a truck flow of about 200 trucks/h, except for a five-man crew where this maximum is reached at 300 trucks/h. Once this maximum point is reached the delays remain constant or reduce. The explanation for this is that as truck flow increases, the delay due to queuing increases up to a maximum, after which the effect of trucks driving through the station with no stationary inspection starts to dominate, so that the average delay starts to stabilize or even decrease.

- The largest increase in average delays at a multi-man station occurs when the crew size increases from two to three men. This is consistent with the large increase in complete inspections (Type 2) that occur when the crew size increases from two to three men as shown in Chart A.

Based on the above observations the following conclusions may be made.

- Increasing the crew size of a multi-man station increases the average delays to trucks if the maximum level of enforcement is maintained.

- Increasing the crew size of a one-man station to two men will decrease the average delays to trucks even if the maximum level of enforce-ment is maintained.

7.2.3/ Manpower Utilization Efficiency

Chart C in Figure 27 shows the levels of manpower utilization for different crew sizes. The chart shows, for example, that at 200 trucks/h, a four-man crew would be utilized for over 90% of the time, whereas, a five-man crew would have a similar level of utilization at 300 trucks/h.

7.3/ Infraction Detection Efficiency

One method of describing the efficiency of a station is the number of trucks that can be inspected. However, it has been previously explained

that there are different levels of inspection varying from a complete inspection which would include both a stationary weight and non-weight inspections, to a moving inspection where the truck is not stopped and the only inspection would be a visual one as the truck passes through the station. This means that the number of trucks inspected is not a true representation of the level of enforcement. For example, the inspecting capacity of a station could be greatly increased by allowing all trucks to drive through the station. Using this inspection procedure only obvious visual infractions, such as license plate infractions, would be detected. Other types of infractions such as over-loading, registration permits, bills of lading, leases, and operating authorities would be difficult to detect without advance knowledge of the infraction.

Therefore a better measure of efficiency would be the infraction detection efficiency, or the proportion of infractors approaching the station that can be detected under a given set of conditions.

A series of simulations were done in order to develop charts showing the relationship between infraction detections within a station and the infraction rate of the trucks on the highway approaching the station. These relationships were developed for varying truck volumes, inspection crew sizes, and station layouts using the same parameters given in Section 7.2. In addition the following parameters have been assumed for infractions:

- ratio of non-weight to weight infractions — 2:1
- percentage of weight infractions not charged because air axles can be adjusted to conform with the weight regulations — 50%
- processing time for weight infractions — 15 min
- processing time for non-weight infractions — 20 min
- re-weigh time at straight layout stations — 5 min
- re-weigh time at racetrack layout stations — 1-1/2 min

Figures 28 to 32 show the relationship between detected infractions and the infraction rates in the truck population on the highway approaching straight layout stations.

Figures 33 to 36 show the same relationship for racetrack layout stations.

In these figures the vertical axis represents the infraction detection rate as a percentage of the entire truck population, and the horizontal axis represents the truck flow per hour on the highway approaching the station. Each curve on the chart represents the variation in the infraction detection rate for different truck flows for a specific infraction rate in the total truck population. For example, the 5% curve in Figure 29 shows that when the truck flow approaches zero, most of the infractions in the truck population will be detected, and the infraction detection rate approaches 5%. As the truck flow increases, a smaller proportion of the infractions is detected, so that at a flow of 200 trucks/h the infraction detection rate is 1%, although the infraction rate of the truck population is 5% (one out of every five infractions is detected).

The figures can be used for the following applications. (They are representative of "typical" rather than specific stations.)

- To monitor the performance of a station.

  For example (see Figure 29), at a straight layout station with a two-man crew, an infraction rate of 5% for the approaching truck population, and a truck flow of 100 trucks/h, the infraction detection rate should be 1.8% (i.e., the infraction detection efficiency is):

  $$\frac{1.8 \times 100}{5.0} = 36\%$$

- To estimate the infraction rate of trucks on a highway approaching a station.

  For example, in the station previously mentioned, if the infraction rate according to the station records was 1.8% of the truck volume on the adjacent highway, the actual infraction rate in the truck population on the highway is 5%. (See Appendix C for further discussion).

- To investigate methods of improving station operational efficiency.

  These are discussed in Section 8.

7.4/ Truck Delays for Different Infraction Rates

Delays to trucks are an important component in the analysis of station efficiencies. The following parameters affect delays to trucks.

- inspection weighing times,
- infraction processing times, and
- method of operating station.

These have been assumed to be the same for "typical" stations and are described in Section 7.3.

Other parameters which affect delays are crew size, infraction rates, truck flows and station layout.

Charts have been produced to show the relationships between these parameters based on simulations for Section 7.3.

Figures 37 and 38 show the relationship between delays, crew size and truck flow for various violation rates at straight and racetrack layout stations respectively.

Chart A in Figure 37 shows the delays for a truck population with 1% infractions and is similar to Chart B in Figure 27, indicating that the effect of infractions does not greatly distort the pattern of delays compared to uninterrupted station operation (i.e., 0% infractions). As the infraction rate of the truck population increases, the effect of infractions becomes more dominant, so that the average delay decreases with increasing truck flow. As truck flow increases, more infractions are detected, the crew spends more time processing infractions, and more trucks pass through the station with moving inspections only (Type 1), thus reducing the average delay to trucks. The relationship of increasing average delays with increasing crew size still holds for multi-man stations as shown previously for uninterrupted operations (0% infractions).

The delay charts shown in Figures 37 and 38 can be used to assess the effects of delays to trucks where modifications to crew size or station layout are contemplated. This is discussed in Section 8.

7.5/ Trucks not Entering Stations

The charts in Figure 39 show the relationship between the percentage of trucks not entering a station, truck flow per hour, crew size and infraction rates for straight layout stations. Charts for racetrack layout stations are not shown since the number of trucks not entering these stations rarely exceeds 5% even at high truck flows and infraction rates.

This information supplements the information on truck delays shown in Section 7.4, where the total delay to all trucks needs to be considered. The total delay to all trucks using the station per shift is calculated as follows.

(Highway truck flow per hour) x (length of shift in hours) x (average delay per truck) x (1.0 - proportion of trucks not entering the station).

7.6/ Parking Capacity

Parking capacity has been included in the simulation model as a constraint. However, this constraint has not been investigated, since parking capacity is not usually a problem, and is rarely exceeded.

Therefore the parking parameters used for the simulations in this section do not affect the operating efficiency of the station.

The following analysis can be used in estimating the parking storage at a particular station.

Number of H.C.I. staff at station is x.
Therefore maximum number of trucks
that can be processed for
infractions at one time = x

Number of staff in a M.V.I.
crew is 2.
Therefore the maximum number

of trucks that can be mechanically inspected at one time = 2

Detained trucks H.C.I. inspections. This would include trucks detained for off-loading, unqualified drivers, etc. This is largely dependent on policy, e.g., policy may change to make truck detention part of the penalty for infractions. Under existing policies the number of detained trucks is rarely more than two = 2

Detained trucks M.V.I. inspections. This would be trucks that are so mechanically deficient that they cannot leave the station until they are repaired = 1

TOTAL PARKING AREA REQUIRED = (5 + x) spaces .

e.g., for a four-man station, provide at least nine parking spaces.

7.7/ Weather Conditions

The effect of weather conditions on the operation of stations was considered from two points of view: trucks using the station and the station crew.

7.7.1/ Trucks Entering the Station

If adverse weather conditions develop which could be hazardous to the station users and/or other users of the adjacent highway, (e.g., snow storm, heavy rain), the station is usually closed. Therefore weather conditions were not considered in the simulation model, since only operating conditions are simulated.

7.7.2/ Station Crew

Weather extremes can affect the behaviour of the station crew. For example, they may be reluctant to leave the weigh house when it is raining in order to perform an inspection outside. Individual attitudes will vary according to personality. However, from discussions with station supervisors, it is understood that inspectors are equipped with the necessary clothing for all weather conditions, and because staff duties are interchangeable, the periods the inspectors have to spend outside the weigh house are not long enough to affect their performance drastically even under severe weather conditions.

Therefore weather conditions have been omitted from the computer simulation model.

7.8/ Summary of Findings

7.8.1/ Weigh Lane Operation

Delays to trucks using the weigh lane are lower if the queue length is limited. Limiting the queue length in the weigh lane also increases the capacity of the weigh lane operation.

7.8.2/ Uninterrupted Station Operation (No infractions)

- The capacity of a one-man station is approximately 30 trucks/h.
- The capacity of the weigh lane at multi-man stations, including non-weight inspections, is independent of crew size. However, the proportion of trucks with non-weight inspections increases with crew size. Up to 125 trucks/h can be processed in the weigh lane.
- Delays to trucks at one-man stations are higher than at multi-man stations.
- Delays to trucks at multi-man stations increase with increasing crew size.
- Delays to trucks at multi-man stations start to stabilize at flows above 200/h.

7.8.3/ Infraction Detection Efficiency

- is very sensitive to truck flow,
- increases with crew size, and
- is higher for racetrack layout stations with the same crew.

7.8.4/ Truck Delays for Different Infraction Rates

For infraction rates higher than 5%, delays to trucks decrease with increasing truck flow, since a large proportion of trucks cannot be inspected due to the crew's occupation with processing infractions.

7.8.5/ Trucks Not Entering Stations

At straight layout stations a large proportion of trucks do not enter the station if truck volumes and infraction rates are high. For infraction rates of 15% and higher, more than half the trucks do not enter the station for flows greater than 300 trucks/h, (See Figure 39).

At racetrack layout stations the proportion of trucks not entering the station is negligible under most conditions.

7.8.6/ Parking, Mechanical Inspections and Weather Conditions

Their effects on station efficiency are usually insignificant.

PART E

METHODS OF IMPROVING STATION EFFICIENCY

8/ GENERAL METHODS OF IMPROVING EFFICIENCY

When considering the overall operational efficiency of a station, three components need to be considered:

- infraction detection efficiency,
- operating costs of the station to the Ministry, and
- delay costs to trucks using the station.

The infraction detection rate is considered to be the best measure of the enforcement efficiency for reasons given previously. However, increasing the efficiency of a station with respect to enforcement may adversely affect station costs and delays to trucks. Therefore all components must be considered concurrently.

The following methods of increasing the infraction detection efficiency of stations have been considered:

- reducing weighing time,
- limiting the length of queues,
- increasing manpower (crew size),
- increasing the surveillance period, (i.e., more than one shift per day),
- modifying the station layout from a straight layout to a racetrack layout,
- reducing processing time for infractions,
- increasing emphasis on non-weight inspections, and
- pre-screening of trucks for inspection.

8.1/ Reducing Weighing Time

8.1.1/ First Weighing Time

At present, most stations use short platform scales so that each truck axle is weighed individually as the truck drives over the scale. The time taken for this weighing operation is given in Section 4.

The use of a five-plate platform scale is presently being evaluated. Using this type of scale the truck drives onto the scale platform and all the axles are weighed simultaneously. It is understood that this method of weighing does not reduce the average weighing time. The main advantage of this system is that trucks do not have to be reweighed in order to record the precise axle weights if a weight infraction is detected.

8.1.2/ Second Weighing Time

As mentioned previously, the five-plate platform scale could reduce or eliminate the need for re-weighing in the case of a weight infraction. However, in many cases the delays in re-weighs are not due to the actual weighing time, but the time spent in adjusting the axle loads of the trucks to comply with the regulations. Therefore, the potential for a five-plate platform scale to increase efficiency is diminished unless adjustments to axle loads can be made outside the weigh lane, so as not to disrupt the flow in the weigh lane.

8.2/ Limiting the Length of Queues

At higher volume stations, delays to trucks can be reduced by limiting the length of the truck queues in the weigh lane. This can be done by diverting trucks to the passing lane when the queue reaches, say, four trucks.

Although this practice will allow potential weight infractors to by-pass the weigh scales, it should not reduce the weight infraction efficiency of the station for the following reasons.

- If long queues are permitted to form in the weigh lane, subsequent arriving trucks will use the passing lane to avoid excessive queuing delays or queuing onto the adjacent highway. Therefore, the loss of potential weight infractions to the passing lane will occur even if long queues are permitted in the weigh lane.

- Temporary station closures due to excessive queue formation in the weigh lane will be prevented. (See Figure 24.)

- The capacity of the weigh lane is increased. (See Section 7.1).

  This practice could be implemented by inspectors outside the weigh house, signalling truck drivers to enter the passing lane when the weigh lane queue exceeds a certain number of trucks.

8.3/ Increasing Manpower (Crew Size)

In many instances, increasing the crew size is an obvious way of increasing infraction detections. However, increasing the crew size will increase operating costs and the average delay to trucks using the station, because a greater proportion of the trucks approaching the station will have stationary inspections. (See Section 7.)

Figure 40 shows the effect of increasing manpower in a straight layout station, with respect to weight and non-weight infractions for a one-way straight layout station, with a 5% infraction rate. As can be seen, the number of non-weight infractions detected is more sensitive to manpower increases than weight infractions. The number of trucks that can be inspected for weight is largely determined by the weighing capacity of the scale rather than the number of inspectors available. Therefore if the objective is to improve weight infraction detection efficiency of a multi-man station, additional manpower will not be effective. If the objective is to improve the non-weight infraction detection efficiency of a station, increasing manpower will be effective.

Figure 41 shows the man hours per infraction detection and truck delays, respectively, for various crew sizes at a station with a 5% infraction rate.

Although the man hours per detection, and truck delays generally, increase as the crew size increases, increasing manpower may be a cost-effective method of increasing infraction detection. A more detailed analysis is required to determine this, as described below.

Table 14 shows how the hourly operating costs of a "typical station" can be determined. As can be seen, the operating costs do not increase proportionately to the increase in crew size, since the fixed operating

costs, capital costs and maintenance costs, are fixed irrespective of crew size.

Table 15 shows how the costs per detected infraction can be calculated for various crew sizes. The example shown in Table 15 represents a one-way straight layout station with a truck flow of 200 trucks/h and 5% infraction rate.

- Column A shows the crew size.

- Column B shows the infraction detection rate for the different crew sizes. These values were obtained from the charts shown in Section 7.

- Column C shows the number of infractions that are likely to be detected during a shift. Seven hours have been considered as the effective operating time to allow 1/2 hour for non-inspection duties (e.g. cleaning and administrative work). The likely number of infractions detected is: the infraction rate x average hourly truck flow (200) x 7 hours.

- Column D shows the operating costs for a 7-1/2 hour shift (7-1/2 x hourly operating cost from Table 14).

- Column E shows the operating costs per infraction detection (Column E divided by Column C).

- Column F shows the average delay per truck.

- Column G shows the total delay in truck hours per shift (average delay x 7 hours x average hourly truck volume).

- Column H shows the cost of delays to truck operators, based on an operating cost of $30 per hour for the average truck.

- Column I shows the delay costs per infraction detection.

o Column J shows the total costs per infraction detection (sum of Columns E and I).

The analysis shown in Table 15 indicates that for this particular example, the overall efficiency of the station with respect to unit cost per infraction detection increases with increasing manpower. Crews of more than five have not been considered, since it is felt that very large crews may be impractical.

Analyses similar to the one shown in Table 15 can be done for individual stations in order to assess the effectiveness of increasing crew size.

8.4/ Increasing the Surveillance Period (Period Station is Open)

This can be done by increasing the number of shifts per day to two or three.

The rationale of adopting an increased surveillance period in order to improve efficiency is to take advantage of the following two factors.

- Fixed costs, capital costs, and to a large extent, maintenance costs, are constant irrespective of how long the station remains open for operation.

- Although extending the surveillance period will result in the station operating more during off-peak periods, the infraction detection efficiency will be higher during these times. Also, average delays to trucks could be lower during off-peak periods.

Table 16 has a similar format to that of Table 15 and shows the unit costs per infraction detection using 1, 2 and 3 shifts per day. The lower truck volumes for the second and third shifts have been included in the analysis. The analysis shows that for this particular example, the unit costs per infraction detection decrease with increasing number of shifts per day, even if the same crew size is used for all shifts. For example, the total unit costs per infraction detection for a three-man crew are $160.37 for a single shift per day, $102.80 for two shifts per day and $89.20 for three shifts per day.

Also, it can be deduced from the example shown in Table 16 that a station with a four-man crew operating one shift per day could be made more efficient by splitting this crew into two 2-man crews and operating two shifts per day. Using this method, the average operating cost per infraction detection could be reduced from $35.63 to $30.44 for single and double shift operations respectively, a savings of 15%.

This saving may be even greater if the infraction rate is higher during the off-peak hours. Also, a longer period of operation may be perceived as a higher level of enforcement by truck drivers.

8.5/ Modifying the Station Layout

Straight layout stations located in areas where additional land is available could be converted to racetrack layouts. These conversions could most likely be made at relatively little expense, since most of the existing station could be retained and the conversion would require only additional grading behind the weigh house. Figure 42 compares the infraction detection efficiencies between straight and racetrack layout stations. The increased efficiencies of the racetrack layouts result from the station remaining open during re-weighs.

Cost analyses similar to those shown in Tables 14 and 15 could be used to calculate the cost/benefits of converting an existing straight layout station to a racetrack layout.

8.6/ Increasing Emphasis on Non-Weight Inspections

In the assessments of individual stations described in Section 9, it appears that stationary non-weight inspections were of secondary importance to stationary weight inspections. This conclusion is based on the observation that the actual non-weight detection rates are often lower than the non-weight detection rates estimated by computer simulation and observations at specific stations.

It appears that the non-weight infraction detections could be increased by increasing the motivation of inspectors to check more trucks for non-weight infractions.

Therefore it is necessary to identify factors which reduce the motivation to perform stationary non-weight inspections. Some of the factors that may be involved are the following.

- Inspectors may feel that the present level of enforcement of non-weight infractions is adequate.

- Inspectors may be reluctant to leave the comfort of the weigh house to perform stationary non-weight inspections.

- Stationary non-weight inspections could involve face to face confrontations with truck drivers, as opposed to the isolated mechanical process of weighing trucks.

The following measures could be implemented in order to ameliorate the above factors' effect on reducing the motivation of inspectors to perform stationary non-weight inspections.

- Information from the study should be used as a feedback to the inspectors performance, indicating that the present level of non-weight infraction enforcement is considered to be unsatisfactory.

- The possibility of providing booths for inspectors outside the weigh house should be investigated. This would probably help reduce the reluctance of inspectors to leave the weigh house in the case of inclement weather and would define a duty post. One possible disadvantage of providing a separate inspection booth outside the weigh house is that it would restrict the possibility of inspecting trucks that are queuing behind the truck at the head of the queue.

- If it is decided to provide inspection booths outside the weigh house the floors (or the booth) should be elevated so that the inspectors eye level is the same as that of a truck driver in a large truck. This would facilitate conversation and exchanging of documents.

The inspection booth and the elevated floor should have the psychological effect of making the inspections less intimidating for the inspectors.

8.7/ Pre-Screening of Trucks for Inspection

Thus far, the computer simulations show that, except for very low truck volumes, it is impossible to inspect thoroughly a large proportion of trucks entering a station. The simulations also indicate that a station can handle very large volumes of moving inspections and the limitations of a station are for stationary inspections rather than moving inspections (see Section 7).

Therefore if an effective pre-screening process could be implemented, the infraction detection efficiency could be improved by using stationary inspections for suspect trucks only. There would also be a reduction in the average delays to trucks using the station.

Pre-screening could be applied to the two major types of infractions: weight and non-weight.

8.7.1/ Pre-Screening for Weight Infractions

Weigh-in-motion scales are currently being tested by the Ministry, and could be very effective in pre-screening trucks for stationary weight inspections. This method of pre-screening is presently deployed in the USA [9]. Figure 43 shows a weigh-in-motion installation.

8.7.2/ Pre-Screening for Non-Weight Infractions

At certain locations, a form of pre-screening for non-weight infractions is possible, where trucks frequent a station often. Once the truck and driver are known to the inspector, only periodic inspection of documents is required.

It is likely that an effective pre-screening methodology could be developed for non-weight infractions at other locations by correlating certain non-weight infractions with such factors as commodity, origin of truck, etc. A program of issuing stickers for display on the truck could be implemented, to indicate that certain inspections are unnecessary, and to facilitate pre-screening. Future developments in communications technology may make it possible to provide terminals at stations, with access to data banks with truck license numbers for pre-screening purposes. (See Appendix for further discussion on pre-screening).

8.7.3/ Example Comparison of Station Efficiency With and Without Pre-Screening

A series of simulations was done for a hypothetical station with pre-screening, and compared with an identical station in which there is no pre-screening.

All other parameters for the station operation were kept the same.

The following pre-screening input was used:

Type 1 Inspections	50%
Type 2 Inspections	10%
Type 3 Inspections	30%
Type 4 Inspections	10%

Figure 44 compares the results of the two simulations. Chart A shows that for a truck flow of 200/h, the infraction detection efficiency increases from 24% to 35% with pre-screening, an increase in detection efficiency of 46%.

Chart B shows that the average inspection delays at the same truck flow reduce from 95 s to 68 s with pre-screening, a saving of 40%. This saving in delays to trucks can be used to estimate fuel savings as shown below.

Calculation of Fuel Saved

- Average reduction in delays to trucks = 95-68 = 27 s/truck.
- Assume station operates 1200 h/yr.
- Therefore number of trucks using station = 1200 x 200 = 240 000 trucks/yr.
- Idling time saved = $\frac{240\ 000 \times 27}{3600}$ = 1000 h/yr.

Diesel fuel saved = 1800 x 2 L/h [12]
= 3600 L/yr.

This example illustrates the potential for improving station efficiency through pre-screening.

8.8/ Optimizing Station Efficiency

Thus far, a number of options have been identified to improve the efficiency of stations. Some of these options may be used singly or in combinations to optimize efficiency.

Table 17 shows a matrix of the possible combinations that could be investigated. It is unnecessary to test all options since many options could be eliminated by inspection. For example, one-man and two-men options would not be investigated for high volume stations.

It is suggested that a format similar to the one shown in Table 16 be adopted for testing various options for improvements. In cases where improvements being considered involve capital expenditure, (e.g., conversion of a straight layout station to a racetrack layout station) these ammortized costs should be added to the operating costs shown in Table 14.

9/ EVALUATION OF SPECIFIC STATIONS

Section 7 described the operational efficiencies of "typical" stations, where factors, such as the ratio of weight to nonweight infractions rates, were assumed. These simulations indicated general trends or principles with respect to station operational efficiencies without being specific to any particular station. Most of the methods for improving efficiency described in Section 8 are based on these principles.

However, in order to improve the efficiency at specific stations, the existing operation must be evaluated before methods of improving efficiency can be explored.

In this section, specific stations were simulated in order to assess their existing operational efficiencies, taking into account conditions that are unique to each station.

Table 18 shows the input parameters used for each station. Two simulations for each station were made, one to represent a day-time shift and the other a night-time shift. The method by which day-time and night-time truck flow were determined was described previously in Section 4.

This section illustrates how the computer simulation model can be used to assess the performance of individual stations and then how this information can be used to identify potential methods of improvements. However, the following should be taken into account when assessing the computer simulation output.

- The computer simulations are based on a rigid inspection procedure whereas different crews may have individual operating styles.
- There may be bias in the way in which trucks are selected for inspection, i.e., a crude form of pre-screening.
- Truckers may try to overcome the system by using the passing lane when they are overloaded.
- Field data used as input are temporal and subject to large variations.
- Since infractions are rare events, and occur at random, long periods of data collection and simulation are required in order to reduce random variations for infraction statistics.

9.1/ Evaluation of Simulations

Table 19 summarizes the simulation output for the eight stations evaluated. Tables 20 and 21 compare the simulated and field data for weight and non-weight infraction detection efficiencies respectively.

The following general comments can be made from the information shown in Tables 19 to 21. As mentioned previously, the field data are subject to large variations and some of the inferences are speculative.

- The weight infraction detection efficiency estimated by computer simulation generally shows an acceptable correlation with that from field for high volume stations, the exception being Station C. At this station the field data indicates a higher weight infraction detection efficiency than that estimated by computer simulation.

  The reason for this may be that Station C has a high proportion of loaded aggregate trucks using the station, and these trucks have a higher probability of being overweight. Therefore the inspectors can increase weight detection rates by concentrating on aggregate trucks.

- At medium volume stations, the infraction detection efficiency estimated by computer simulation shows significant variation from the field data. At Station E, one explanation may be that the station is used for training purposes. At Station D, part of the variation for weight infraction detections may reduce by extending the computer simulation period so that the percentage of weight infractions detected (65%) approximates the percentage of trucks with stationary weight inspections (59%) (See Table 20).

- At low volume stations, the field data indicate a higher weight infraction detection efficiency than that estimated by computer simulation. The reason for this is that in the computer simulation model equal importance is given to stationary nonweight inspections and, since the low volume stations have only one inspector, the weighing capacity is reduced. However, based on field observations at various stations, the normal practice is to give priority to stationary weight inspections over stationary non-weight inspections.

- For all stations, except Station H, the simulated non-weight infraction detection efficiency is higher than that indicated by field data. This confirms what has been observed in the field, i.e., that inspectors give priority to weight inspections over stationary non-weight inspections.

- The simulated infraction detection efficiencies are approximately equal to the simulated percentages of trucks inspected. The variations are due to the stochastical nature of the simulation model.

9.2/ Evaluation of Specific Stations for Possible Improvements

Evaluation summaries for each of the eight stations are shown in Tables 22 to 29. These are used to identify areas of improvement which may be investigated further.

A description of each box in the table follows.

(i) Box A shows the existing parameters for the station.

(ii) Box B compares the existing with the simulated infraction detection efficiencies and comments on the existing performance of the station. The computer simulation output is specific to each station.

(iii) Box C evaluates the following possible improvements.

- Increasing crew size by one inspector. If increasing the crew size is significantly beneficial, increases of more than one inspector could be investigated further.

- Converting the station to a racetrack layout. This has not been considered for low volume stations.

- Extending the period of surveillance by considering double shifts with the same crew size.

The evaluation of possible improvements is based on simulation output produced for the "typical" stations in Section 7. The reason for this is

that because of the stochastical nature of the simulation model, a series of simulations for each individual station would have to be done, so that the output could be "smoothed" graphically to eliminate random variations.

Although the output from the "typical" stations simulations will, in most cases, differ from that of simulations for specific stations, it is felt that the "typical" station output is sufficiently accurate for the purposes of identifying and evaluating alternative improvement possibilities.

(iv) Box D summarizes the recommendations, if any, for improving the operational efficiency of the station.

TABLES AND FIGURES

TABLE 1

WEIGHT INFRACTION DETECTION EFFICIENCY

COLUMN TRUCK INSPECTION STATION	1 INFRACTION RATES - SPECIAL SURVEY 1980	2 INFRACTION RATES - REGULAR SHIFTS 1980	3 PERCENT OF INFRACTIONS DETECTED	4 PERCENT OF TRUCKS ENTERING T.I.S. INSPECTED	5 PERCENT OF TRUCKS ON HIGHWAY INSPECTED
A	1.08	0.33	31%	28%	28%
B	1.63	0.52	32%	32%	26%
C	1.64	0.87	53%	39%	37%
D	1.18	0.53	45%	39%	38%
E	1.45	0.23	16%	44%	22%
F	8.84	2.51	28%	73%	52%
G	1.04	0.63	61%	29%	29%
H	1.58	1.17	74%	36%	36%

Source (2)

TABLE 2
NON-WEIGHT INFRACTION DETECTION EFFICIENCY

TRUCK INSPECTION STATION	INFRACTION RATES - SPECIAL SURVEY 1980	INFRACTION RATES - REGULAR SHIFTS 1980	PERCENT OF INFRACTIONS DETECTED	PERCENT OF TRUCKS INSPECTED
E	1.45	0.17	12%	11%
G	4.14	1.17	28%	5%
B	5.06	0.52	10%	2%
H	1.58	1.04	66%	13%
A	1.68	0.41	24%	5%*
D	1.44	0.16	11%	6%
C	3.13	0.75	24%	5%*
F	8.37	2.51	30%	11%

* Estimates

Source (2)

TABLE 3

WEIGHT AND NON-WEIGHT INFRACTION RATES

TRUCK INSPECTION STATION	INFRACTION RATE PER 100 VEHICLES INSPECTED			RATIO OF NON-WEIGHT TO WEIGHT INFRACTIONS
	WEIGHT	NON-WEIGHT	TOTAL	
Bowmanville	1.45	1.45	2.89	1.00
Curry Hill	2.47	5.02	7.05	2.03
Fort Erie	0.54	1.97	2.51	3.65
Fruitland	0	0.90	0.90	-
Gananoque North	1.36	9.13	10.50	6.71
Gananoque South	0.78	7.83	8.62	10.04
Glen Tay	1.04	4.14	5.18	3.98
King	0.57	3.03	3.60	5.32
Lancaster	2.46	3.57	6.03	1.45
Lorne Park	1.63	5.06	6.69	3.10
North Bay South	1.58	2.81	4.39	1.78
Oakville	1.08	1.68	2.76	1.55
Putnam North	0.88	0.58	1.46	0.66
Putnam South	1.18	1.44	2.62	1.22
Streetsville North	0.93	2.37	3.30	2.55
Streetsville South	1.64	3.13	4.77	1.91
Thunder Bay South	8.84	8.37	17.10	0.95
Victoria	7.68	4.75	12.43	0.62
Wasi	2.41	5.63	8.05	2.34
Whitby	1.26	3.79	5.05	3.01
Windsor North	1.23	4.60	5.82	3.74
Windsor South	0.63	4.69	5.32	7.44
Winona	0.57	1.02	1.59	1.79
Woodbridge	0	3.11	3.11	-

Source (2)

TABLE 4
CAPITAL COSTS (1980 VALUES)

TRUCK INSPECTION STATION	STATION LAYOUT	CONSTRUCTION COSTS $	LAND COSTS PER ACRE $	NO. OF ACRES	COST OF LAND $	TOTAL COSTS $	ANNUAL AMORTIZATION COSTS* $
A	One-Way Racetrack	592,000	40,000	5.9	236,000	828,000	110,852
B	One-Way Straight	484,750	40,000	5.8	232,000	716,750	95,958
C	One-Way Straight	484,750	40,000	5.8	232,000	716,750	95,958
D	One-Way Straight	484,750	1,000	5.8	5,800	490,550	65,675
E	One-Way Straight	484,750	2,000	5.8	11,600	496,350	66,451
F	Two-Way Straight	484,750	300	5.8	1,740	486,490	65,131
G	Two-Way Racetrack	484,750	2,000	5.8	11,600	496,350	65,451
H	Two-Way Straight	484,750	500	5.8	2,900	485,250	64,965
I **	Two-Way Straight	484,750	300	5.8	1,740	486,490	65,131
J **	One -Way Straight	484,750	1,000	5.8	5,800	490,550	65,675

* 12% interest over 20 years
** Construction costs may be higher due to large parking areas and difficult site conditions

Source (7)

TABLE 5

MAINTENANCE COSTS

TRUCK INSPECTION STATION	FISCAL YEAR			AVERAGE
	77 - 78	78 - 79	79 - 80	
A	8,974	16,975	11,369	12,439
B	8,869	5,511	7,384	7,255
C	11,635	6,455	8,328	8,806
D	-	-	-	6,943*
E	9,588	-	1,600	5,594
F	-	-	-	6,943*
G	-	-	12,234 -	6,117
H	-	-	-	6,934*
I	-			6,934*
J	-	-	-	6,943*

* No data available, average from other stations.

TABLE 6

TOTAL COSTS - 1980 VALUES

TRUCK INSPECTION STATION	CAPITAL COSTS $	MAINTENANCE COSTS $	SALARIES* $	TOTAL ANNUAL COSTS $ **
A	110,852	12,439	95,319	218,610
B	95,958	7,255	95,319	198,532
C	95,958	8,806	72,552	177,316
D	65,675	6,943	72,552	145,170
E	66,451	5,594	72,552	144,597
F	65,131	6,943	27,018	99,092
G	66,451	6,117	27 018	99,586
H	64,965	6,943	27,018	98,926
I	65,131	6,943	27,018	99,092
J	65,675	6,943	49,785	122,403

* T.I.S. supervisor $27,018 per year (includes benefits)
T.I.S. inspector $22,767 per year (includes benefits)
** Station assumed to be open for the whole year

TABLE 7

DELAYS FOR TRUCKS USING ONE WAY LAYOUT STATIONS

(Excludes delays for queuing and inspection)

DELAY COMPONENT	A	B	C	D	E	J
Delay decelerating to enter T.I.S. via ramp and driving to weigh house	12	6	6	6	6	6
Delay accelerating from weigh house to posted highway speed	55	55	55	55	55	55
TOTAL DELAY (SEC.)	67	61	61	61	61	61

TABLE 8

DELAYS FOR TRUCKS USING TWO WAY LAYOUT STATIONS

(Excludes delays due to queuing and inspections)

	F		I		G		H	
DELAY COMPONENT	RAMP ENTRANCE	LEFT TURN ENTRANCE	RAMP ENTRANCE	LEFT TURN ENTRANCE	RAMP ENTRANCE	LEFT TURN ENTRANCE	RAMP ENTRANCE	LEFT TURN ENTRANCE
Delay decelerating to make left turn	-	13	-	13	-	8	-	↑
Delay executing left turn and driving to weigh house	-	15	-	40	-	15	-	↑
Delay decelerating to enter T.I.S. via ramp and driving to weigh house	34	-	38	-	10	-	10 estimated	NOT USED
Delay driving from weigh house to T.I.S. exit Stop sign	22	22	40	40	22	22	22	NOT USED
Delay accelerating from exit Stop sign to posted highway speed	42	42	42	42	34	34	14	↓
TOTAL DELAY	98	92	120	135	66	79	46	↓
AVERAGE TOTAL DELAY	95 seconds		128 seconds		73 seconds		46 seconds	

* I operates as a two way racetrack layout T.I.S.

** H operates as a one way straight layout T.I.S.